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Project Report on A Pedal-Operated Seed Cleaner (PoS-Cleaner) To Boost Post Harvest Grain & Legume Quality, Increase School-Study time & Create Financial Freedom in Rural-Uganda. Submitted to Makerere University Research and Innovations Fund (Mak-RIF)

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Prepared

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Project Summary

About the Project

Post-harvest handling processes such as drying, threshing, and storage have progressed among small scale farmers in developing countries. However, there is still a lag in technology interventions addressing cleaning. It is uncertain whether this lag is attributed to technology access or the unnecessary for cereal and pulse cleaning technology. This work assessed the effect of access on the use of improved cleaning technologies for seeds as compared to drying, threshing, and storage technologies among key farmers in Kamuli district, Uganda. Challenges and opportunities to access and use postharvest handling technologies were taken into consideration. A needs' assessment survey in post-harvest handling technologies was done. Pre-set questionnaires were administered in face to face interviews to 200 farmers who had been purposively selected. This was followed by developing five pedal-operated seed cleaners (PoS-Cleaner) that were distributed to five farmer groups, but positioned at host farmers' residences based on intermediated technology use and technology acceptance approach. Findings suggest that ownership, awareness, and distance, which are measures of technology access, influence technology use to a greater extent. There is a maximum distance which farmers with quantities of produce for cleaning may not go beyond to access the services of the available improved cleaning technology in the area. Irrespective of the positioning of the cleaners limiting their flexibility in terms of movement from one household to another, produce cleaning using the improved machine was found necessary given that farmers with 200-800 kg of produce for cleaning endured to push it on bicycles to and fro, over a total distance of 3-4 km to access and use. Capitalizing on this maximum distance, farmers can access and use technologies expensive for them to own, if positioned within a radius of 1km. This would improve timely unit operations, reduce postharvest handling losses and exposure to dust during cleaning.

2. Value addition of the project

The pedal operated seed cleaner is able to clean over 500 kg/h of maize and 280 kg/h of beans compared to less than 100 kg/h using the traditional cleaning baskets, trays and sieves.

3. Good practices (If applicable)

The PoS-Cleaner reduces seed loss withing the chaff and dust, accomplishes the cleaning tusk in a timely manner and the user of the technology is not exposed to dust like when using trays and baskets.

4. Project and community testimonies

Figure 0 shows the distances farmers moved to access and use the PoS-Cleaner. This is a testimony showing the necessity of the improved seed cleaning technologies among smallholder farmers. It can be seen that a farmer with 800 kg of produce endured a distance of 2 km to access and use the cleaner and there after carry back the cleaned produce through the same distance, totaling to 4 km. It should be noted that bicycles were the ones used to push the produce.

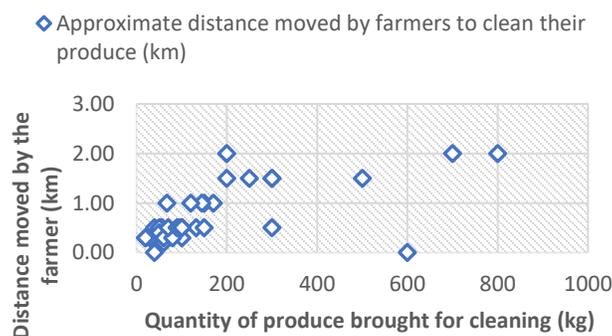


Figure 0: Distances farmers moved to access and use the PoS-Cleaner and quantities cleaned



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5. Engagement pictures



6. Lessons learnt

- i. If an expensive technology is available and farmers are aware, hire service may improve its use
- ii. Technology use is greatly influenced by ownership, awareness and accessibility distance
- iii. A maximum distance exists which farmers with given quantities of produce may not go beyond to access technology services
- iv. Technology flexibility in terms of portability is key in technology acceptance and use
- v. Provided a technology is necessary, users will move to access and use it irrespective of its limited flexibility in terms of movement from one household to another
- vi. Farmers were found treating signs and symptoms of low yields by depending on loans for school fees without knowing that low yields were the cause of less revenue and high household expenses.

7. Media mentions and publications

The media link below gives more information on engagement with farmers using the developed seed cleaner
<https://www.newvision.co.ug/news/1525273/farmers-clean-produce>

Peter Tumutegyeize, Isaac Oluk, Julia Kigozi, Ismail Mayanja, Thomas Buyinza, Moureen Mbeiza. (2020). Assessing the Effect of Access on the Use of Improved Seed Cleaning Technologies; Challenges and Opportunities among Farmers in Kamuli District-Uganda. *Submitted to World Development Journal*.

Wilber Akatuhurira, Peter Tumutegyeize, Isaac Oluk, Emmanuel Baidhe, Julia Kigozi, Ismael Mayanja & Hussein Balimusi Kivumbi. (2020). Development and Performance Evaluation of a Pedal Operated Seed Cleaner (Post-Cleaner) For Seeds with Diameter Size Range Of 6.6 – 18mm. *Submitted to SN Applied Sciences Journal*.



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Acronyms

CAES	College of Agricultural and Environmental Sciences
CBOs	Community Based Organizations
CE	Cleaning Efficiency
FAO	Food and Agriculture Organization
ISU-UP	Iowa State University -Uganda Programme
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
NGO	Non-Governmental Organization
PoS-Cleaner	Pedal Operated Seed Cleaner
SACCO	Savings and Credit Cooperative Organizations
SDG	Sustainable Development Goals
TAM	Technology Acceptance Model
UBOS	Uganda Bureau of Statistics
UC	University of California
VSLA	Village Savings and Loan Associations



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1. Introduction

Cereals and pulses form the largest percentage of carbohydrate and protein sources for the majority population in the developing countries. In Uganda, cereals and pulses account for 25 % and 14 % respectively of the crop area (FAO, 2003). Most of the food supply comes from small scale farming (operating on less than 2 acres). Taking an example of beans where an estimated 60-90% is attributed to small scale farming (MAAIF, 2018a). As such, a lot of effort in terms of research funding has been directed to developing varieties that are high yielding, maturing in a short time, and resistant to pests and diseases to create favorable farming conditions for small scale farmers. However, limited funding or research has been allocated to developing postharvest handling technologies to handle the increased yields. In contrast to developed countries where advanced post-harvest handling technologies such as combine harvesters are used for threshing, cleaning, and temporary storage, manual methods are still employed in developing countries even on a large scale. It must be noted that the limited research that has focused on postharvest handling technologies of cereals and pulses in developing countries has focused on threshing, drying and storage neglecting the unit operation of cleaning (Tefera et al., 2011; Kumar & Kalita, 2017; Bradford et al., 2018; River et al., 2018). Yet, cleaning is considered to be one of the most effective unit operations in reducing levels of Mycotoxins in grains (Bullerman & Bianchini, 2007). Apart from threshing using sticks, there are now both manual and motorized shellers or threshers that small-scale farmers can have access to use. Similarly, hermetic storage methods have been developed such that farmers can access other than the traditional systems of storage like heaping in house, open-air hanging, and traditional granaries (Omotilewa et al., 2018). Whereas drying, threshing and storage technologies have moved a step, cleaning operation remains lagging among small scale farmers who form the largest percentage of cereal and pulse supplies in developing countries. In Uganda, much of the cleaning of cereals and pulses is done by women using baskets and trays. This traditional screening or winnowing said to be inefficient, time consuming, labour intensive, coupled with 4% of total production losses (Kumar & Kalita, 2017), low revenues and ill health exposure resulting from inhalation of dust (Tibagonzeka et al., 2018). For rural schools that depend on in-kind food tuition contributions from parents, pupils traditionally clean seeds hence reducing their study time and educational performance. Certainty as to why appropriate technology interventions addressing cereal and pulse cleaning as a unit operation in postharvest handling are lagging among small scale farmers remains unclear. Is it a question of technology access or the technology of cereal and pulse cleaning is not necessary? Technology access is being looked at in terms of technology presence, ownership, awareness or proximate distance to the technology being favorable. In this context, access is being considered as the right or opportunity to use or benefit from the technology as defined in the Oxford dictionary. Therefore, this work aimed at assessing the effect of access on the use of improved appropriate cleaning technologies for cereals and pulses as compared to drying, threshing, and storage technologies among key farmers in Kamuli district, Uganda. However, challenges and opportunities to access and use postharvest handling technologies were also taken into consideration. This was in light of the fact that a technology may be available and farmers fail to use it due to other underlying challenges apart from access or they may have alternative technologies better than the technology of interest.



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In the work by Norris et al., (2003), it is suggested when there is no access to a technology, there will not be use of the technology as well its impact. Further, it points out that the strongest predictors of technology use are measures of technology access. Given that most of the work done on technology access and use has been focusing of information technology, this work looked at technology access and use in post-harvest handling unit operations.

2. Approach

2.1. Survey approach

To assess the effect of access on use of improved cleaning technologies for cereals and pulses in relation to drying, threshing and storage technologies, a household survey was first conducted. During the survey, purposive sampling was used. It was necessary to identify potential farmers without random sampling such that if they are found to be vulnerable in terms of lack ownership and awareness of improved postharvest handling technologies, income insecurity, diseases exposure, stress, drudgery and exploitation by middlemen, then, the other farmers who are on the lower level would also be vulnerable. Therefore, 200 key farmers who have their own land and have been practicing production of maize, beans and ground nuts for a long period of time were identified with the help of Iowa State University-Uganda Program (ISU-UP), an NGO that works in Kamuli-Uganda, in three sub counties of Butansi, Nabwigulu and Namasagali in Kamuli District. The study area represents a suitable example where most of the sustainable development goals (SDG) are far from being met. In these sub counties, 11.6-15.9% of female aged 10-19 years have given birth, 11.8-17.1% of youth aged 18-30 years are not in school and not working, 13.9-16.9% of children aged 6-12 years are not in school, 33.9-61.2% of the households are 5 km and above from the nearest public health facility and 4.3-8.5% of the households have less than 2 meals a day (UBOS, 2017). In addition, most households in this study are rent out their land to sugarcane out growers, which leaves them with limited or no land for food production. This suggests that the area is characterized by food insecurity and malnutrition. This is one of the reasons why ISU-UP is operating in this area having established centres where it provides diets to under age expectant and breast-feeding mothers, school going children and the elderly. The selected farmers are considered as trainer farmers who are expected to train others. Interviews were conducted face to face using a preset questionnaire per the selected farmer or household. Among the key parameters that were assessed are post-harvest handling technology ownership, awareness, use, accessibility distance, land size ownership, crop yields, challenges to unreliable income, membership to any savings group, access to loan, loan security and loan use.

In order to establish whether access to seed cleaning technologies is necessary, five pedal operated seed cleaners were developed and distributed to five farmer groups which are active in grain crop production in Butansi and Namasagali sub counties. The cleaner consists of a bicycle-like pedaling system, hopper, a centrifugal fan and three cleaning sieves which include two inside interlocking sieves and one fixed; whose meshes can be adjusted to be larger than the size of the unclean seeds by simply translating the second sieve to achieve the appropriate seed size (Figure 1). This allows trapping of foreign impurities larger than the seeds. The outer third sieve has mesh holes smaller



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than both unclean seeds hence eliminating impurities smaller than the seeds. The fan and sieve rotary motion derived from pedaling supports seed continuous movement through the sieves due to gravity and centrifugal forces. During operation, the unclean seeds are fed into the hopper which then flow down gravitationally. At this stage, light foreign materials are blown off by the centrifugal fan. This first separation stage utilizes the difference in aerodynamic property of the materials being separated. After, the seeds are channeled to the sieves for further separation and cleaned seeds are collected in one receptacle. Host farmers for the machines among the five groups were selected based on their potential to provide space and security for the machine as well as potential to train other farmers on the use and operation of the machine. Figure 2 shows farmers learning how to use one of the machines at the residence of the host farmer. This method was informed by work done by Sambasivan et al., (2010) on intermediated technology use in developing countries where, persons for whom technology is inaccessible due to barriers like lack of awareness, financial constraints, lack of technology and skills for operation, are enabled to benefit from technologies through second or third party who have no access barriers to the technology. A data collection sheet was also provided so that whoever uses the machine, registers his or her subcounty, parish, village, type of seed brought for cleaning, quantity cleaned, time taken and remarks for feedback. Distances between the residences of the hosts of the seed cleaners and farmers who brought produce for cleaning were also approximated. This was intended to establish the effect of distance on machine use since it is one of the factors that limits one to benefit from any available technology or service. By doing this, time to market, flexibility, integration, and user satisfaction which are considered to be the main variables of concern in the technology acceptance model (TAM) (Hong and Yu, 2018) were tested. Measuring time taken to clean a given quantity of produce was related to variable of time to market enables users to accomplish very complex tasks in a short period of time. In addition, this also measured user satisfaction given that if the rate of produce cleaning is below or equal to what farmers have been getting while using their traditional cleaning technologies, then, user satisfaction is not met. However, if it is much higher, the user is satisfied. Given that the piloted pedal operated seed cleaners could not be moved from one farmer to another, it has no flexibility in terms of movement. This limitation in flexibility was used to show the usefulness and necessity of the technology. Integration on the other hand which refers to a technology being used in conjunction with existing systems as reported by Hong and Yu, (2018), was said to be assessed if farmers used the pedal operated seed cleaning machine instead of their traditional cleaning technologies.

2.2. Design of the pedal-operated seed cleaner components

2.2.1. Hopper

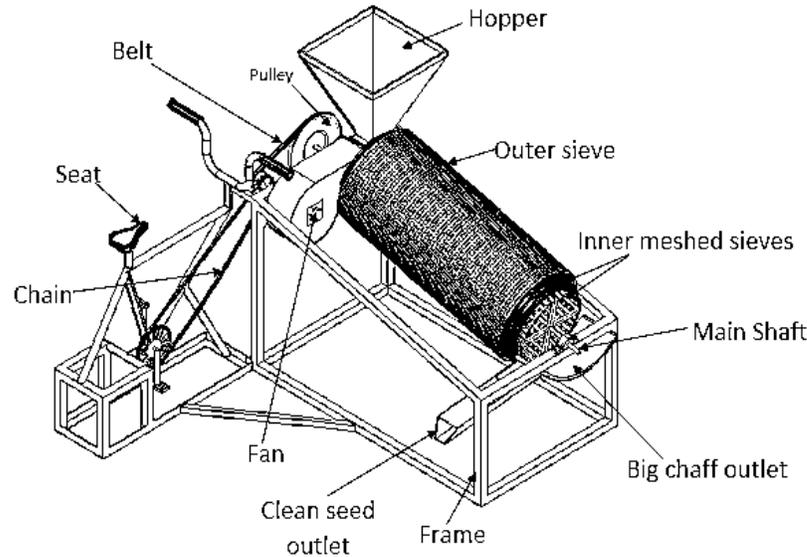


Figure 1: Assembly of the Pedal Operated Seed Cleaner

The hopper shape is of a square-base pyramid frustum. The volume of the hopper was determined using Equation (1) (Mayanja et al., 2018).

$$V = \frac{H}{3} (A_1 + A_2 + \sqrt{A_1 \times A_2}) \quad (1)$$

Where V is the volume of a hopper (m^3), h is the height of the hopper (m), A_1 is the area of the top part of a hopper (m^2) and A_2 is the area of the bottom part of the hopper (m^2)

Hopper capacity for the different grains was determined using Equation (2).

$$M = \rho \times V \quad (2)$$

Where ρ is the density of the grain

2.2.2. Trommels (Rotating sieves)

The three sieves rotate in tandem. The two inner sieves are meshed together and can be adjusted longitudinally to vary the mesh hole size to clean grains of varying sizes. The efficiency of cleaning generated from the trommels (rotary sieves) depends on its length, diameter, speed, and angle of inclination (Bellocq, Ruiz, Delaplace, Duri, & Cuq, 2017). The length and diameter of these sieves should be long enough to provide for more time of contact of the seeds to be cleaned (Lee & Lee, 2020). The desired operating speed of trommels is computed relative to the critical speed, the speed at which a centripetal acceleration of $9.8m/s^2$ at the screen surface is achieved (Amoah, Aggey, Addo, & Abdulai, 2017). According to (Mayanja et al., 2018), the best operating speed of the rotating sieve ranges from 33% to 45% of the critical speed. Critical speed (N_c) was determined from the sieve radius using the relationship in Equation (3) (Amoah et al., 2017).

$$N_c = \frac{30}{\pi} \sqrt{\frac{g}{R \sin \theta}} \quad (3)$$



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Where N_c is the critical angular speed of the sieve (rpm); R is the radius of the sieve(m); g is the acceleration due to gravity (m/s^2); θ is the maximum angle of lifting approximated to be the angle of friction (degrees).

2.2.3. Belt and pulley design

(a) Length of the belt

The pedal operated seed cleaner has two pulleys with a belt connection to transmit power from the chain drive to the trommels. The diameter of the pulley is given by the relationship in Equation (4) (Khurmi & Gupta, 2005).

$$\frac{d_1}{d_2} = \frac{N_2}{N_1} \quad (4)$$

Where d_1 is the diameter of the driver pulley (m), d_2 is the diameter of the driven pulley (m), N_1 is the speed of the driver pulley (rpm), N_2 is the speed of the driven pulley (rpm)

The length of the belt (L) depends on the diameter of the driven and driving pulleys and the center distance between the pulleys given by the relationship in Equation (5) (Khurmi & Gupta, 2005).

$$L=2C+1.57(d_1+d_2)+\frac{(d_2-d_1)^2}{4C} \quad (5)$$

Where C is the center distance between two adjacent pulleys (m) determined by Equation (6) (Sobowale, Adebisi, & Adebo, 2015)

$$C=\frac{d_1 + d_2}{2} + d_1 \quad (6)$$

(b) Tension in the tight and slack side of the belt

Tension in the tight side of the belt (T_1) is created on that section of the belt approaching the driver pulley. Tight side tension is a function of both maximum tension and centrifugal tension. Tight side tension is given by Equation (7) (Khurmi & Gupta, 2005).

$$T_1 = T_{\max} - T_c \quad (7)$$

Where T_{\max} is the maximum allowable tension in the belt (N) given by Equation (8) and T_c is the centrifugal tension in the belt given by Equation (9) (Sobowale et al., 2015).

$$T_{\max} = \sigma \times A_1 \quad (8)$$

$$T_c = mv^2 \quad (9)$$

Where σ is the stress for the belt material (N/m^2), m is the mass per unit length of the belt (kg/m), v is the speed of the belt (m/s) determined by Equation (10) (Sobowale et al., 2015), and A_1 is the cross-sectional area of the belt (m^2) determined using Equation (11).

$$v = \frac{\pi N_1 D_1}{60} \quad (10)$$

$$A_1 = \left(\frac{B + x}{2} \right) t \quad (11)$$

Where B and x are the outer and inner belt breadth respectively (mm), t is the belt thickness (mm)



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Slack side tension is created on the section of the belt approaching the driven pulley. The slack side tension (T_2) of the belt is given by Equation (12).

$$2.3 \log \left(\frac{T_1}{T_2} \right) = \mu \theta \csc \beta \quad (12)$$

Where β is the half groove angle (degrees), θ is the angle of lap on the smaller pulley (radians) given by Equation (13), and μ is the angle of friction between the belt and the pulley (unitless)

$$\theta = \left(180 - 2 \sin^{-1} \left(\frac{r_1 - r_2}{C} \right) \right) \frac{\pi}{180} \quad (13)$$

Where r_1 and r_2 = radii of the big and small pulleys (mm) respectively.

(c) Power transmitted by the belt

The power required in transmitting the belt (P_1) was determined using Equation (14) (Khurmi & Gupta, 2005)

$$P_1 = (T_1 - T_2)v \quad (14)$$

2.2.4. sprockets and chain drive design

The driver and driven sprockets are connected through a chain. The driven sprocket (small) runs at the same speed at the driver pulley in the belt-pulley arrangement. The driver sprocket (Big) runs at a speed determined by the relationship given by Equation (15) (Khurmi & Gupta, 2005).

$$N_s T_s = N_b T_b \quad (15)$$

Where N_s is the speed of rotation for the small sprocket (rpm), N_b is the speed of rotation for the big pulley (rpm), T_s is the number of teeth for the small sprocket, T_b is the number of teeth for the big sprocket.

The length of the chain (L_c) was determined using Equation (16) (Khurmi & Gupta, 2005).

$$L_c = Kp \quad (16)$$

Where K is the number of chain links given by Equation (17) (Khurmi & Gupta, 2005) and p is the pitch of the chain

$$K = \frac{T_s + T_b}{2} + \frac{2C_c}{p} + \left[\frac{T_b - T_s}{2\pi} \right]^2 \frac{p}{C_c} \quad (17)$$

Where C_c is the center distance between the sprockets (mm)

The power transmitted by the chain (P_2) based on breaking load was determined using Equation (18) (Khurmi & Gupta, 2005).

$$P_2 = \frac{W_b \times v_c}{n \times k_s} \quad (18)$$

Where W_b is the breaking load (N), n is the factor of safety, v_c is the velocity of the chain given by Equation (19), and k_s is the service factor given by Equation (20) (Khurmi & Gupta, 2005).

$$v_c = \frac{T_p N}{60} \quad (19)$$

Where N is the speed of rotation (rpm), T is the number of teeth,

$$k_s = k_1 \times k_2 \times k_3 \quad (20)$$

Where k_1 , k_2 , k_3 are the load factor, lubrication factor, and rating factor respectively.



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2.2.5. Power required to operate the machine

The total power required to run the machine was calculated by summing the power required in transmitting the belt and the chain given by Equation (21).

$$P = P_1 + P_2 \quad (21)$$

2.2.6. Design of Sieve shaft

(a) Shaft diameter

The diameter of the shafts was ascertained mathematically using Equation (22) (Mayanja et al., 2018).

$$D^3 = \frac{16}{\pi \tau_s} \sqrt{(K_B M_B)^2 + (K_T M_T)^2} \quad (22)$$

Where D is the diameter of the shaft (m), K_b is the combined shock and fatigue factor applied to bending moment, K_T is the combined shock and fatigue factor applied to torsional moment, τ_s is the allowable shear stress for bending and torsion (N/m^2), M_B is the maximum bending moment (Nm) given by Equation (23) (Mayanja et al., 2018), M_T is the torsional moment (Nm) given by Equation (24).

$$M_b = \sqrt{M_h^2 + M_v^2} \quad (23)$$

Where M_h is the horizontal component of the bending moment (Nm), M_v is the vertical component of the bending moment (Nm). The maximum bending moment was divided into vertical bending moments M_v and the horizontal M_h since the loadings are acting in different directions.

$$M_T = (T_1 + T_2) \frac{D_2}{2} \quad (24)$$

Where T_1 is the tension in the tight side of the belt (N), T_2 is the tension in the slack side of the belt (N), and D_2 is the diameter of the driven pulley (m)

(b) Shaft design based on torsional rigidity

This angle of twist was used to establish if the shaft was safe. The angle of twist was determined using Equation (25) according to (Olusegun, Emeka, Afolabi, & Alake, 2018).

$$\theta = \frac{584 M_T L}{G D^4} \quad (25)$$

Where, θ is the angle of twist (degrees), M_T is the torsional moment (Nm), G is the torsional modulus of rigidity (N/m^2), L is the length of the shaft (m).

2.2.7. Design of centrifugal blower

A blower is used to move the air constantly with a slight increase in static pressure to allow for separation of the grain-chuff mixture. The blower air discharge was estimated using the expression of continuity as given by Equation (26) (Olusegun et al., 2018)

$$Q = A_4 V \quad (26)$$



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Where Q is the air discharge (m^3/s) A_4 is the area of the blade (m^2) and V is the velocity of air (m/s) produced from the blower

2.3. Optimization of the cleaning process

The geometric mean diameter was used to estimate the grain size. A sample of 25 grains was picked from maize, beans, and groundnut batches. Using a vernier caliper, the grain dimensions (length, width, and thickness) were measured and used to calculate the geometric mean diameter for maize, beans, and groundnuts using Equation (27) (Yenge, Kad, & Nalawade, 2018).

$$\text{Size} = (a \times b \times c)^{\frac{1}{3}} \quad (27)$$

Where a is the length (mm); b is the width (mm); c is the thickness (mm) of the grain

The inner sieve was then adjusted based on the size of grains. Ten kilograms of maize were mixture with known volumes of undesirable material. The inner sieve was adjusted to 12 mm and the mixture was then fed into the cleaning machine after which pedaling was done at 60 rpm. This is because lower cadences are known for lower energy demands (Abbiss, Peiffer, & Laursen, 2009). The weight of clean maize collected at the clean seed outlet was determined using a digital weighing scale. The experiment was done in duplicate and an average was taken. The same procedure was repeated when the inner sieve was set at 13, 14, and 15 mm respectively. The respective cleaning efficiencies were determined using Equation (30). The process was repeated for beans with inner sieve holes adjusted to 14, 15, 16, and 17 mm and for ground nuts with inner sieve holes adjusted to 8, 10, 12, 14, 16 mm. The values of cleaning efficiency were compared to establish the highest values. The sieve hole size at which the cleaning machine recorded the highest cleaning efficiency was taken to be the optimal sieve hole size for the grain while pedaling at 60 rpm.



Figure 2: One farmer group learning how to use the seed cleaner machine



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3. Study findings and discussion

3.1. Level of technology ownership, awareness and use

Table 1 presents the level of ownership of some selected postharvest handling technologies and awareness. It shows that even when the farmers are aware of the technology, ownership may not be possible if the cost of that technology is high, given that cost is also one of the access barriers (Porter and Donthu, 2006). This is explained by the awareness percentage of tarpaulin for drying and bags for storage which is 100% for each of them but their percentages of ownership are far too different. It can be seen that tarpaulin has a low ownership percentage of 41.7% while storage bags have 78%. This is probably due to the cost difference between tarpaulin and a storage bag. That is, tarpaulin is over fifty times higher than the cost of a bag. However, if the technology is available but expensive, and farmers are aware, hire service seems to be favored. This is supported by the percentage of awareness of the threshing machine (77.6%) and its hire service percentage of 92.4%. Table 2 on the other hand presents percentage use of the different postharvest handling technologies. Comparing Tables 1 and 2, it can be said that ownership and awareness of a technology influence use of the technology to a greater extent. Taking cleaning machine as an example, whose percentage of awareness is 12.6% and ownership percentage is 0% by individual and 1% by group basis, its percentage use is very low (2%) compared to the other technologies whose awareness and ownership percentages are higher. This supports Norris et al., (2003) argument that having one unit of a technology (machine) in a community is not access, nor will it lead to significant community use. In addition, the lack of awareness probably explains partly the 93.9% of why farmers are still heavily relying on the traditional methods of cleaning using trays and baskets.

Table 1: Level of selected postharvest handling technology ownership and awareness by percentage

Attribute	Tarpaulin	Threshing machine	Winnowing machine	Storage bags
Individual ownership	41.7	5.7	0	78
Group ownership	0	7.6	1	0
Hire		92.4	1	
Aware of technology	100	77.6	12.6	100

Table 2: Level of use of postharvest handling technologies by percentage

Postharvest activities							
Drying Technology	% use	Threshing Technology	% use	Cleaning Technology	% use	Storage Technology	% use



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Tarpaulin	32.2	Sticks	64.5	Winnowing baskets/trays	93.9	bags	78
Bare ground	58.3	Thresher/sheller	22.5	Cleaning machine	2.0	drums	4
Tarpaulin and bare ground	9.5	Sticks and thresher/sheller	13.0	Winnowing sieves	4.1	hip in house corner	17.5

3.2. Effect of distance on use of seed cleaner by farmer groups

Table 3 presents a one-month feedback on access and use from three seed cleaners out of the five that were distributed. It should be noted that the harvesting season was towards the end when the farmer groups received the seed cleaners and farmers would go to clean their produce when they wanted in their own time. However, of the two hosts that did not send feedback, one closed home and went somewhere for some time after receiving the machine while the other host is a training center which was not operating as supposed due to covid-19 restrictions. This suggests that technology use depends on access. This is further supported by Figure 3 which shows the approximate distances farmers travelled to the seed cleaner hosts with respect to the quantities of produce that needed to be cleaned. Regardless of the limited flexibility in terms of movement of the cleaning machine from one household to another, farmers were able to carry their produce to be cleaned, showing the necessity of the technology. It should be noted that both men and women were involved in the cleaning process, indicating the role of improved technology is gender balance. It is generally shown that farmers who brought their produce for cleaning were from within a radius of 2 km. In addition, it was only farmers with 200 kg and above that found it necessary to carry their produce in a distance of more than 1 km for cleaning. This implies that farmers with small quantities found it not worthwhile to move long distances to access the technology. However, if the seed cleaners were within their reach, they would use them irrespective of the quantity. This is evidenced by the fact that the majority who used the machine were within 1 km and less with less than 200 kg of produce for cleaning. Note that farmers with zero distances moved are the host farmers of the seed cleaners. Given that farmers with large quantities of produce were the ones who moved long distances to access and use the seed cleaners, it suggests that there is a relationship between distance to access a technology and the quantity of produce to be cleaned. That is, there is maximum distance beyond which a farmer with a given quantity of produce to be cleaned cannot exceed to access a technology for use. Further, it proves the necessity of postharvest handling cleaning technologies for seeds as well as the magnitude of the problems associated with seed cleaning using the local technologies. From the survey, over 90% of the respondents reported that winnowing with baskets and trays was associated with diseases due to dust, time consuming and tiresomeness. Paining of cheeks after a long day of seed cleaning using trays was singled out as a major problem among women. It is important that as efforts to improve productivity with high yielding varieties continue, attention should be put on developing and availing technologies for cleaning. Like threshing machines that have been integrated in the system through hire service, seed cleaning machines can be integrated in the



system through the same, since farmers showed that they are needed. Further, governments can capitalize on this maximum distance by positioning postharvest handling technologies expensive for farmers to own within radii of 1 km to improve their access and use.

Table 3: One-month feedback on seed cleaner access and use

No	Farmer group area	Seed cleaner location	Number of users	Quantity of maize cleaned (kg)	Quantity of beans cleaned (kg)
1	Bugulu zone, Bwiiza parish-Namasagali subcounty	N0° 57.676' E32° 59.179'	6	280	27
2	Kabanyolo zone, Namasagali parish-Namasagali subcounty	N 1° 01.408' E32° 57.416'	17	3490	295
3	Bugogo Zone, kiwungu parish-Butansi subcounty	N0° 54.224' E33° 04.146'	21	2630	-
4	Bugeywa Zone, Bugeywa parish-Butansi subcounty	N0° 54.786' E33° 01.743'	-	-	-
5	Butegere Zone, Naluwoli parish-Butansi subcounty	N0° 56.323' E33° 03.601'	-	-	-

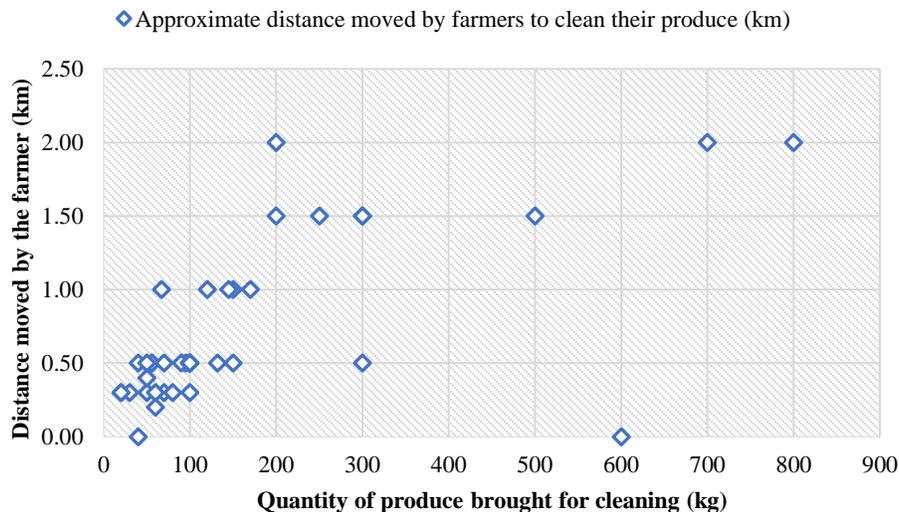


Figure 3: Approximate distances moved by farmers to the seed cleaner host with respect to the quantities of their produce needed to be cleaned



3.3. Optimization of the cleaning process

Figure 4 shows the variation of cleaning efficiency (CE) with sieve size. It is observed that the cleaning efficiency is initially low but increases with increasing sieve size for all grains. The low CE at smaller sieve sizes is attributed to the inability of the grains to fall through the sieve, therefore ending up in the chaff. At a very large sieve size, the CE is observed to reduce for all grains. This could be a result of excessive infiltration of the undesired materials into the grains, which is eventually collected at the clean grain outlet. Upon optimizing the sieve size for the different grains, results indicate that maize, beans, and groundnuts had their highest CE of 95.09%, 87.61%, and 81.67% at the inner sieve size of 13 mm, 16 mm, and 10 mm respectively.

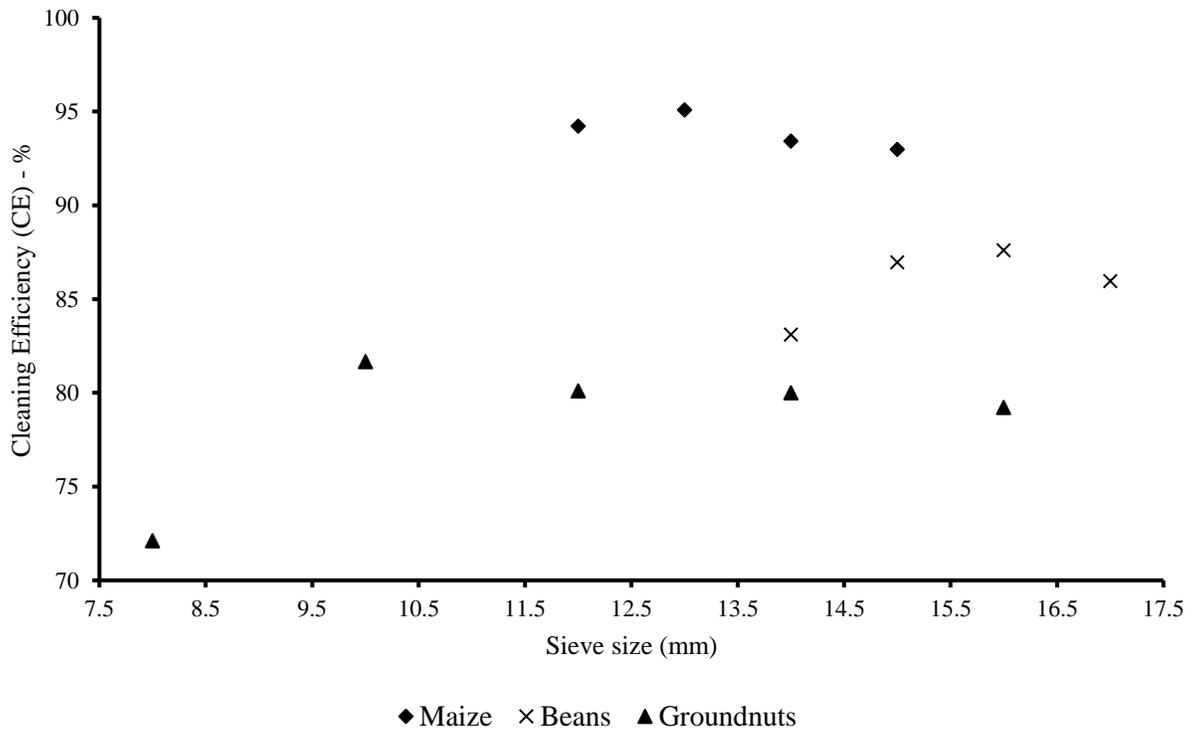


Figure 4: A plot of cleaning efficiency against sieve size

3.4. Feedback on seed cleaner timeliness by farmer groups

Figures 5 and 6 show the quantities of maize and beans respectively from different farmers that were cleaned by the machines and the time each farmer took to complete the cleaning process using the machine. From the equations of best lines of fit, 516.9 kg and 288.1 kg of maize and beans respectively can be cleaned by the seed cleaner in an hour. These values are not far from what had been determined using 10 kg of both maize and beans. Cleaning rates of 571 kg/h and 375 kg/h of maize and beans respectively had been determined by extrapolation basing on 10 kg



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of each produce that was used for testing. Therefore, one can confidently say that the seed cleaner can clean over 500 kg/h and 280 kg/h of maize and beans respectively. In comparison with existing practices, 94.4% of respondents reported taking more than five hours to clean their produce, whereby 76.4% reported yields of over 5 bags before cleaning. On the other MAAIF (2018ab) reported a blanket figure for both maize and beans as 100 kg/h for an individual using tray or basket and 500 kg/h using a sieve. However, 500 kg/h with a sieve never factored in the time to sort out large constituents which the seed cleaner takes care of. On the other hand, if using a sieve would achieve 500 kg/h as given by MAAIF, (2018ab), then, no farmer would bear the burden of pushing 200-800 kg of maize on a bicycle for a distance of 1.5-2 km looking for a cleaner and then pushes it back after cleaning, considering the conditions of village roads. In this regard, time to market and user satisfaction were met by the machine's higher rates of cleaning of over 500 kg/h for maize and 280kg/h for beans, compared to what farmers normally achieve when using trays, baskets and sieves.

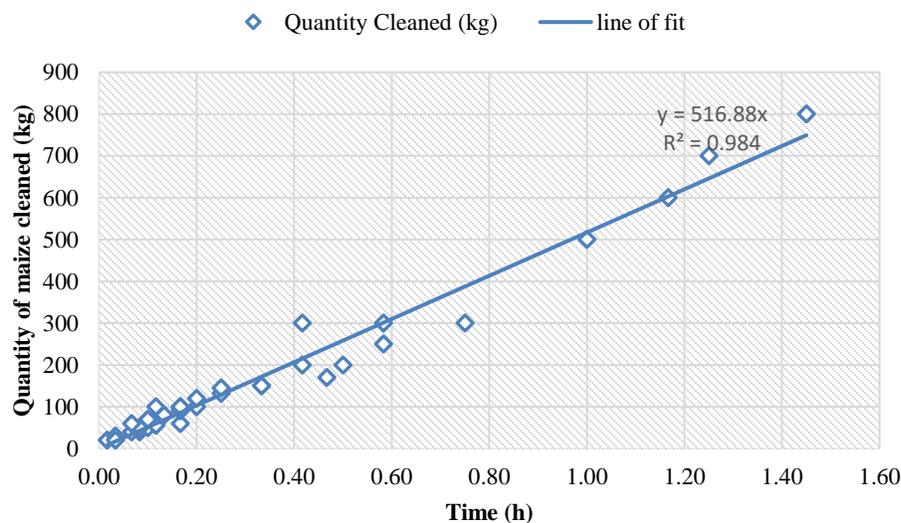


Figure 5: Quantities of maize brought by farmers for cleaning with respect to time taken

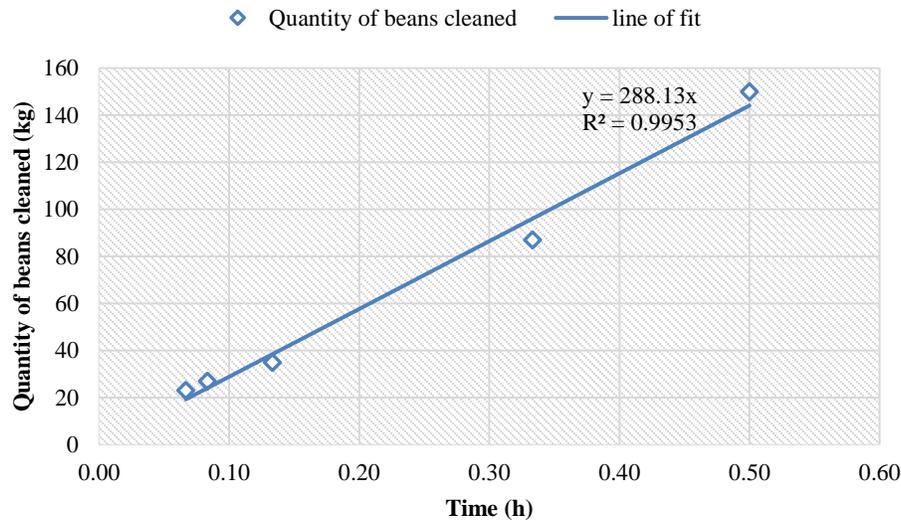


Figure 6: Quantities of beans brought by farmers for cleaning with respect to time taken

3.5. Challenges and opportunities to access and use postharvest handling technologies

From the survey, 65.7% reported income not reliable due to three main factors contributing 96% of the respondents. These factors are less revenue from produce, high household expenses and postharvest loss. There is an opportunity underlying this challenge given that 92.5% of the farmers were found belonging to certain Village Savings and Loan Associations (VSLA) or Savings and Credit Cooperative Organizations (SACCO), although, only 63.9% were active members. Collective marketing would give them bargaining power, thus enhancing their incomes. However, this opportunity of collective marketing was only found being exploited by only 3.5% of the respondents while 83% reported middlemen coming for their produce from their homes. Furthermore, if collective marketing was adopted, access to postharvest handling technologies would be much easier. For instance, in the case where farmers pushed 200-800 kg of produce on bicycles (Figure 3) to the cleaning machines and back covering a total distance of 3-4 km, the machine would be positioned at the collecting center so that the farmer does not have to carry the produce back after cleaning. In this way, the farmers would save their energy and time by carrying once their produce instead of twice. As already highlighted in Section 3.2, over 90% of the respondents reported that winnowing with baskets and trays was time consuming, tiresome and associated with diseases due to dust. Table 4 shows the time farmers take while cleaning their produce using baskets and trays. Working in groups would enable farmers access technology through credit or hire purchase which individuals may not be in position to achieve. Moreover, by the time this interview took place, 65% of the farmers had taken loans of which 84% of these had taken the loan in less than 12 months back. In addition, the loans taken were most especially used for paying fees as shown in Figure 7. To secure loans, 22% used their land as mortgage, 32.7% were recommended by those who trusted them that would pay back, 29% took salary loans and



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4.3% used their houses as mortgage. Given that the respondents were purposively sampled based on those who own land and were using it to grow maize, beans and groundnuts, this implies that those do not have land or are marginalized, have limited chance of securing loans since they cannot get security for the loan like land, recommender or salary. This indicates that children of the marginalized households drop out of school since their parents have limited chances of securing a loan for school fees like the households who have land. However, this dependence on loan to take children to school puts probably all households in a vulnerable position of not being able to purchase a technology on individual basis. Also, storage space was found to be limited for 51% of the respondents which can be addressed through bulk storage in groups.

In respect to the cleaning machines that were positioned at the residences of host farmers, those who used the machines to clean their produce suggested modification on the machines in order for them to be moved from household to household. It should be noted that the seed cleaners that were distributed had no wheels to be pulled like some of the threshing machines. The machines are also large in size to be carried by motorcycles which farmers depend on to carry threshing machines that do not have wheels. Amidst this challenge of machines being in one place, farmers are continuing carrying their produce to and fro, to have it cleaned. This shows the need or necessity for improved technologies to handle the cleaning unit operation that has been lagging when compared to drying, threshing and storage operations. It also shows the underlying challenges farmers face during cleaning of their produce.

This work has revealed gaps in the value chain of crop production that need attention by innovators, extension workers in areas of soil fertility management, post-harvest handling, social to financial, NGOs, CBOs, governments. First, about 91% of the respondents were found to have more than 1 acre of land which to some extent agrees with the 61% of the respondents having more than 5 bags of maize harvest. Although the phrase “more than 5 bags” was not defined to be specific, MAAIF, (2018b) states that current average maize yield per acre to be between 0.89 MT and 1.01 MT compared to the potential yield of 3.2 MT/acre. Considering the quantities of maize farmers carried for cleaning to the cleaning machines, none was in the range of 0.89-1.01 MT. Worse still, 89.7% were below 5 bags which is contrary to the survey data. Partly, one would probably argue that farmers carried a portion of their harvest to be cleaned. However, what is being revealed in this finding is that use of questionnaire method to determine parameters at households, may not show exactly the situation on ground. By availing a new technology (seed cleaning machine), farmers probably brought out all they had harvested for cleaning. The farmers who carried 2 to 8 bags of maize for cleaning most probably, was all they had, which are far below the current average yield range of 0.89-1.01 MT/acre, without considering the potential yield of 3.2 MT/acre. It is surprising that none of the respondents suggested low yields as one of the causes of unreliable income. Only 2.4% of the respondents reported that they had small pieces of land which relates to small quantities of harvest. This suggests that farmers know that the land sizes at their disposal is sufficient but they probably do not know the yields expected from their land. The underlying main cause of less revenue, failure to meet household expenses and postharvest loss as the factors for unreliable income, that farmers may not be aware of, is probably low yields as revealed in the presented analysis. These low yields point to soil degradation, impacts of climate



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change, poor agronomical practices, limited or no extension services as well as limited resources in terms of labour and capital to put in place what would be needed to increase yields. Since 100% of the respondents were directly engaged in farming as their primary source of income, the effects of low yields directly affect attaining goals number 1 and 2 of no poverty and zero hunger respectively of the Sustainable Development Goals (SDG). In addition, low yields hinder the quality of health and well-being, quality of education, economic growth as well as industry development, which are all part and parcel of the SDG. For instance, the effect of low yields on the quality of education is depicted in Figure 5, where majority of the households depend on loans to take children to school. Therefore, this calls for new innovative approaches from government agencies and researchers when determining household parameters if the SDG are to be practically fully attained.

The other gap identified in this study is that the seed cleaner machines that were piloted among farmers can only handle seeds in the range of 6.6-18 mm in size (maize, beans and groundnuts). However, farmers in the developing countries grow rice, soya beans and many other crops with smaller seed sizes whose unit operation of cleaning has no improved technology to address it. This is an opportunity that can be tapped into.

Table 4: Farmers yield percentages of maize and time taken during cleaning using trays and baskets

Yield (100 kg bags)	Before cleaning (%)	After cleaning (%)	Time taken (h)
<2	5.5	9.0	<3
2-3	4.5	9.5	3-4
3-4	6.0	5.5	4-5
4-5	7.5	13.1	>5
>5	76.4	61.8	>5



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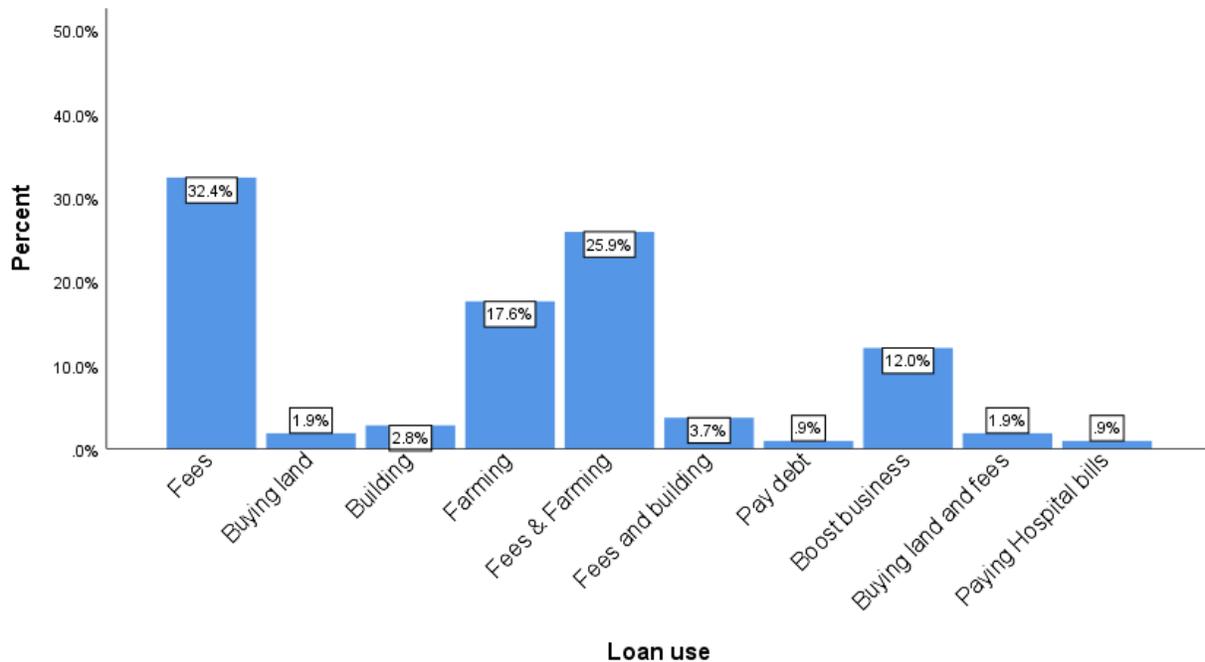


Figure 7: Response by percentage for the use of loans secured by farmers

4. Conclusion

Irrespective of the limited or no flexibility of the pedal operated seed cleaning machine in terms of movement from one household to another, farmers including both men and women, carried their produce to where the machines were stationed for cleaning and back. This proved the necessity of improved technologies for the cleaning unit operation. Although farmers moved to use the machines, the study established that there is maximum distance beyond which a farmer with a given quantity of produce to be cleaned cannot exceed to access a technology for use given that farmers with quantities less than 200 kg were from within a radius of not more than 1 km from the seed cleaners' host farmers. While on the other hand, farmers with 200-800 kg were from within a radius of 1.5 to 2 km. Improved seed cleaning technology was found necessary since farmers with 200-800 kg of produce for cleaning endured to push it on bicycles to and fro, over a total distance of 3-4 km to access and use the cleaner. It is important that as efforts to improve productivity with high yielding varieties continue, attention should be put on developing and availing technologies for the cleaning unit operation as well.

Results from the use of the seed cleaner by farmers show that the seed cleaner is able to clean over 500 kg/h of maize and 250 kg/h of beans, which are about five times higher than what can be achieved by the commonly used trays and baskets. This partly meets user satisfaction and time to market parameters important for any technology development to be acceptable.



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Less revenue from produce, high household expenses, postharvest loss, time consuming, drudgery, disease susceptibility and dependence on loans were the main challenges farmers are experiencing. However, if these farmers took advantage of collective marketing, of which over 90% were found belonging to certain farmer groups, they would have bargaining powers over their produce, thus enhancing their income and potential to secure technologies through credit or hire purchase like the seed cleaner, relieving them of drudgery, time wastage, postharvest losses and disease susceptibility.

During the face to face interviews using a questionnaire, 76.4% of the farmers suggested that they harvest more than 5 bags of maize. However, analysis of data collected during the piloting of the seed cleaning machine, show that 89.7% of those who carried their maize for cleaning were below 5 bags contrary to the survey results. Although low yields were not reported as one of the challenges during the survey, what is has been revealed is that low yields, is probably the underlying cause of less revenue that results into failure to meet household expenses and school fees. In addition, this implies that new innovative approaches of carrying out household baseline surveys are needed if reliable demographic variable information to base on for planning is to be attained.

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Appendix A: Traditional post-harvest cleaning technologies of seeds

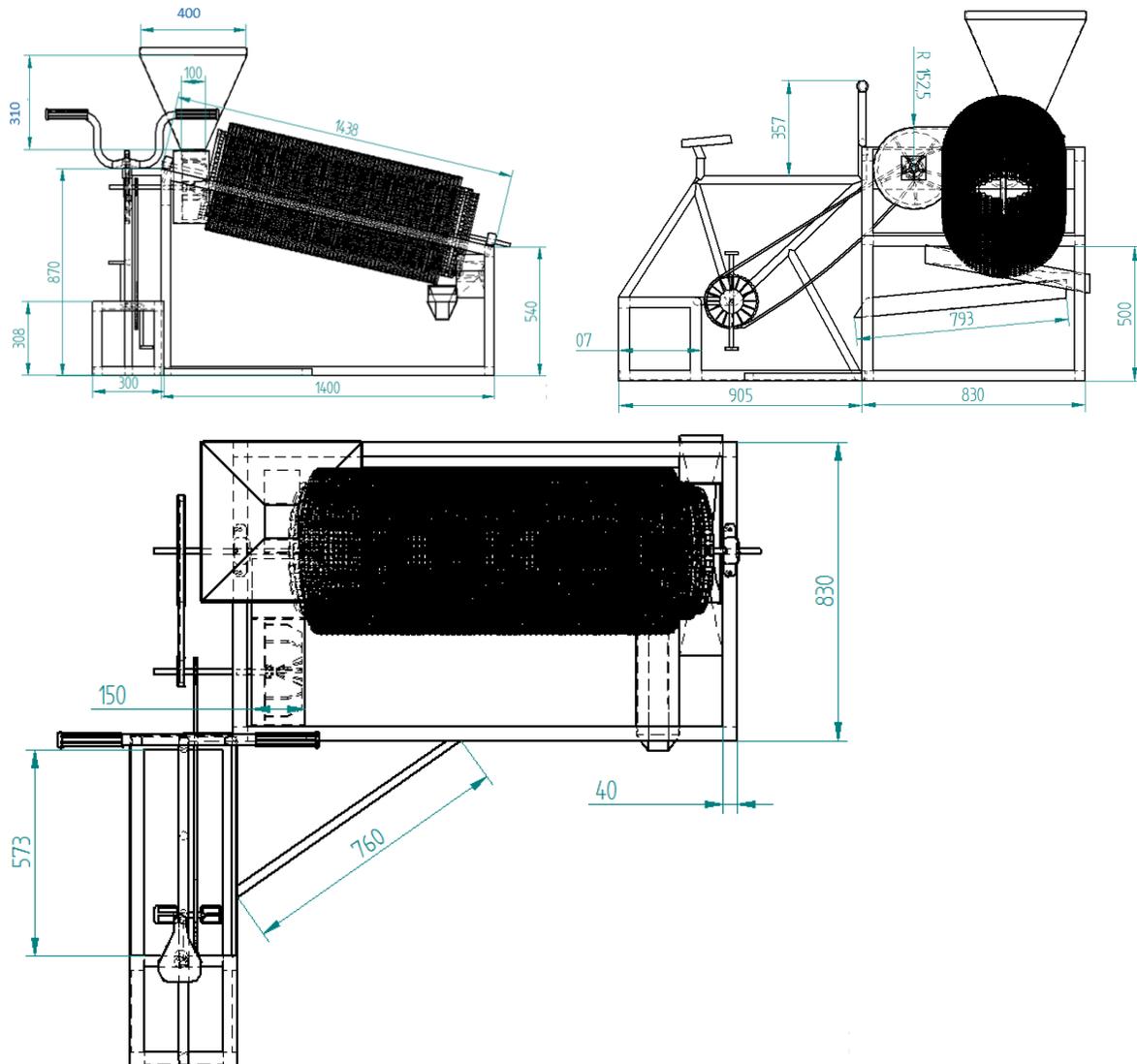




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Appendix B: Production drawings





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Appendix B: Farmers using the Improved seed cleaning technology

